UNITED STATES AIR FORCE MATERIALS TECHNOLOGY HIGHLIGHTS

Air Force Research Laboratory

Materials & Manufacturing Directorate

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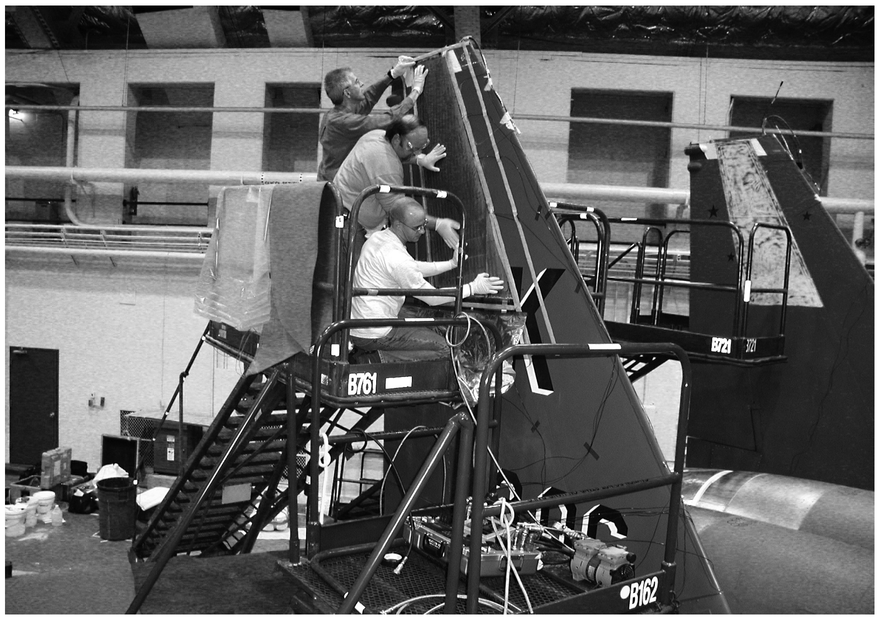
Bonding and Inspection Processes Strengthen F-15E Vertical Stabilizers

Engineers at the Air Force Research Laboratory's Materials and Manufacturing Directorate (AFRL/ML) resolved a serious and potentially expensive problem affecting the stability and design life of F-15E vertical stabilizers.

Working with Warner Robins Air Logistics Center, the Directorate's Systems Support Division successfully developed, demonstrated and transitioned a bonding process and nondestructive inspection (NDI) procedure to ensure stiffening doublers attached to each side of both stabilizers remain adequately secured.

F-15E aircraft have been losing their doublers during takeoff and in flight. The new bonding process, developed by the Division's Adhesives, Composites and Elastomers Team, along with a thermography-based NDI procedure developed and fine-tuned by engineers from the Nondestructive Evaluation (NDE) Team, provides greater safety for F-15E flight crews, and substantial savings for the Air Force in vertical stabilizer replacement costs.

Both of the F-15E's vertical stabilizers require composite stiffening doublers (two per stabilizer) to reduce in-flight vibrations, which can reduce the lifespan of the stabilizers by up to 25 percent. The doublers also help prevent the forward box from cracking, which could seriously threaten the integrity of the aircraft. Unfortunately, the original bonding process used to secure the doublers to the F-15E proved inadequate and led to extensive re-work to replace the doublers that had become damaged or detached. Following multiple cases of the stiffening doublers separating from the aircraft during takeoff or in flight, engineering placed a hold on further modifications until a permanent fix preventing bonding failures could be implemented.



Technicians install stiffening doubler on F-15E vertical stabilizer.

Engineers in the ML Systems Support Division successfully developed, demonstrated and provided an approved version of a new adhesive bonding process and NDI procedure to resolve the problem. They affixed two doublers, using the new bonding approach, to an F-15E undergoing maintenance at Warner Robins Air Logistics Center. By July 2003, the doublers had accrued about 250 hours and were carefully inspected (on station) at Elmendorf AFB, Alaska, where the aircraft was then assigned. They were found to be in perfect condition and the green light was given to implement the new bonding and inspection processes throughout the entire F-15E fleet. This transition began with the remaining two doublers being installed onto the test aircraft. The new processes were then handed over to depot teams at Seymour Johnson AFB, N.C., for installation on a second fighter.

Improvements over the original bonding process include: the addition of holes in the doublers to allow air bubbles to escape during the vacuum/cure process; increased initial strength through a reduction in the quantity of bond line voids (from >15 percent to <3 percent) and better bond line thickness control (>20 mils (thousandths of an inch or >.020 inches) to <14 mils using glass beads instead of nylon fishing line); improved surface preparation procedures (grit blasting surfaces versus hand abrading); simplified application of adhesive (i.e. using pre-measured kits specially fabricated for this application versus mixing from quart kits in the field); and the application of heat to cure the adhesive versus room temperature curing, resulting in reduced repair time, improved wetting of the surfaces, and better adhesive properties.

The NDI procedure implemented a thermography inspection, in lieu of a previous ultrasonic inspection, which resulted in reduced inspection time and (continued on page 4)

B-52 Systems Program Office Adopts ML-Developed, Fire-Resistant Hydraulic Fluid

A fire-resistant hydraulic fluid developed by a team of experts from the Air Force Research Laboratory's Materials and Manufacturing Directorate recently completed a B-52 flight test and will be adopted for use in over 90 percent of the aircraft's components.

According to B-52 system engineers at Oklahoma City Air Logistics Center, revisions to the B-52 technical order will be official by January 2005. OC-ALC will also conduct tests to determine if the landing gear struts and wing tip protection struts can also be converted to the fire-resistant fluid.

Air Combat Command's B-52 is a long-range, heavy bomber that can perform a variety of missions. The bomber is capable of flying at high subsonic speeds at altitudes up to 50,000 feet. It can carry nuclear or conventional ordnance with worldwide precision navigation capability. In a conventional conflict, the B-52 can perform air interdiction, offensive counter-air and maritime operations. During Operation Desert Storm, B-52s delivered 40 percent of all the weapons dropped by coalition forces. It is highly effective when used for ocean surveillance, and can assist the U.S. Navy in anti-ship and mine-laying operations. Two B-52s, in two hours, can monitor 140,000 square miles of ocean surface.

Hydraulic fluids are a critical, safety of flight material for all Air Force aircraft. Hydraulically actuated mechanisms are responsible for a large number of aircraft functions, including highly sophisticated flight controls, landing gear operation, the control of rudder flaps, and accessory door actuation. In addition, hydraulic fluids also lubricate aircraft systems and remove heat from components as it is generated during their operation.

The hazards associated with the flammability characteristics of hydraulic fluids are well known. They are required to function in high-pressure hydraulic systems in the presence of a variety of ignition sources. Though fire-resistant fluids will burn, they are significantly more difficult to ignite and/or have a lower propensity to propagate a fire after ignition than a non-fire resistant fluid.

Nonstructural material experts from the directorate's Fluids and Lubricants Group have dedicated significant research and development activities to preventing hazards caused by hydraulic fluids. Two synthetic hydrocarbon based fire-resistant hydraulic fluids were successfully developed to meet the requirement, and were compatible with the systems and design of aircraft, including the B-52, that were using the flammable 5606 fluid.

A program in the 1960s and 70s first led to development of MIL-PRF-83282, a fluid that is compatible with, and is an appropriate drain-and-fill replacement for 5606. It also didn't require any type of retrofit of hydraulic system materials or components.

Conversion of DoD aircraft to this fluid was authorized and accomplished across the board except for aircraft that were required to be airborne on short notice. Those aircraft were not converted because the viscosity of 83282 was higher at –65 degrees Fahrenheit than that of 5606. Aircraft using 83282 were found to require longer warm-up times for the flight controls before the aircraft could take-off, a phenomenon that was considered unacceptable. So those aircraft continued to use the flammable fluid, 5606.

A requirement was subsequently developed for a compatible, drain-and-fill replacement hydraulic fluid for 5606 that would have the same low temperature operational capability, but would also offer improved fire resistance.

Based on a modified synthetic hydrocarbon polyalphaolefin and a similar additive package, the group developed the new fluid (MIL-PRF-87257), which extensive testing and evaluation proves is an appropriate replacement for the older, flammable hydraulic fluid in all military and commercial aircraft.

The improved fluid's higher flash point, and reduced flammability is expected to increase aircraft survivability and the operational safety of the B-52. In addition, thermal stability measurements, and fluid film thickness data, demonstrate that the improved fluid (MIL-PRF-87527) is usable in temperatures as low as -65 degrees Fahrenheit as well as in high temperature environments for extended periods of time.

Scientists and engineers from ML have continually sought to develop, promote and push improved fluids and lubricants for application in the field because of their safety, cost and operational benefits to both the user and aircraft maintainers. With conversion of the B-52 to a fire resistant hydraulic fluid, only a few Air Force aircraft still use the flammable MIL-PRF-5606. ML experts are hoping that continued exposure to the benefits of the fire-resistant fluids will encourage other Systems Program Offices to convert to one of the safer, superior-performing fire-resistant hydraulic fluids in the near future.

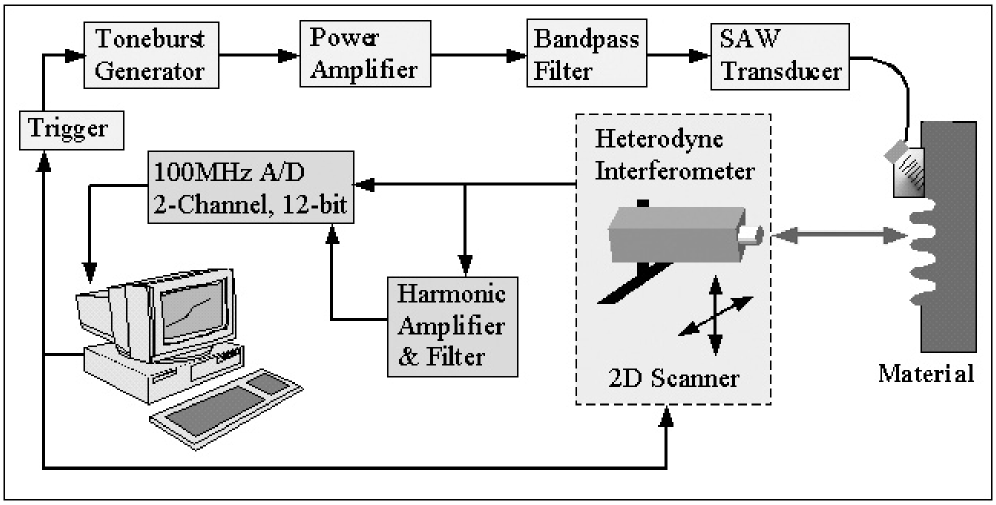
For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 04-328.

Air Combat Command's B-52 bomber.

Scientists Advance Development of Ultrasonic System That Would Revolutionize Nondestructive Evaluation

Scientists at the Air Force Research Laboratory Materials and Manufacturing Directorate (ML) developed a prototype nonlinear laser ultrasonic nondestructive evaluation (NDE) system that can measure and assess localized fatigue damage in a material with high sensitivity and resolution.

The new system provides a means for visualizing the fundamental and harmonic displacement fields propagating as surface and bulk acoustic waves. It has already proven highly effective for several material substrates, and has excellent potential for a diverse range of industrial applications. Continued research and development efforts will serve to revolutionize NDE by facilitating the ability to follow the fatigue state of critical structural components from cradle-to-grave.



Schematic diagram of nonlinear laser ultrasonic detection system.

For more than 50 years, the NDE community has focused on detecting and characterizing fatigue cracks as the primary means for assessing the remaining life in Air Force systems. A recent trend in NDE research has been assessment of a material through its entire fatigue life. Rather than waiting for a crack to initiate, which usually indicates failure is eminent, scientists would monitor the gradual accumulation of damage in the material. If this were possible (if continuous assessment of fatigue state could be accomplished), the implications would be profound and revolutionary.

One of the most promising NDE techniques for monitoring accumulated fatigue damage in materials is nonlinear ultrasonics. In recently years, several researchers have reported significant changes in nonlinearity parameters generated in fatigued aluminum 2024-T4, stainless steel 410Cb and titanium Ti-6Al-4V alloys. The reported measurements clearly show changes in nonlinear parameters due to fatigue by the time the material undergoes 30 to 40 percent of its total fatigue life. Researchers have also reported correlations between dislocation density levels within the fatigued material and increases in harmonic ultrasonic signals.

Scientists in the Directorate's Metals, Ceramics and NDE Division developed a nonlinear laser ultrasonic system and used it to characterize the fatigue state of a fractured Ti-6Al-4V sample with high spatial-resolution and sensitivity.

The measurement system they employed was built around a scanning heterodyne interferometer, which allows detailed displacement field images to be created and visualized for propagating surface and bulk acoustic fields on a material surface. They assessed the local fatigue damage to the sample using nonlinear ultrasonic interaction principles, where the local amplitudes of the fundamental and second harmonic displacement fields are monitored simultaneously. This allowed them to evaluate the local acoustical nonlinearity parameter, β, which can be related to the accumulation of fatigue damage in a material. The ML research team observed a large increase in β between the unfatiged area (near the grip section) and the heavily fatigued area (gauge section) for a fractured dogbone specimen. These measurements revealed the potential for spatially-resolving the local fatigue state of a material using laser ultrasonics.

Building on this progress, the team developed a prototype nonlinear laser ultrasonic NDE system that can image the fundamental and harmonic ultrasonic displacement fields in several material substrates. Their measurements included both non-fatigued and fatigued materials (titanium, aluminum, and nickel superalloys). The objectives of their work were: to test the feasibility of using an advanced laser ultrasonics NDE system to image local fatigue state; explore the possibility of using bulk ultrasonic waves (for volumetric measurements), and surface acoustic waves (for surface fatigue measurements); and evaluate the sensitivity and resolution aspects of the technique for imaging the local fatigue state.

Although high-resolution images of the nonlinear 'beta field' were not possible due to ultrasonic wave diffraction effects, the feasibility of imaging harmonic ultrasonic fields generated by material dislocations and fatigue was achieved. ML researchers also showed that detecting sub-picometer ultrasonic motions with laser ultrasound was feasible with high signal-to-noise ratio SNR levels and microscopic resolutions.

The technical and engineering impact of this project will be substantial for ML, the Air Force, and the entire NDE community. This effort will provide a means for the Air Force and the Department of Defense to assess high-performance weapon systems for the entire life of each system. It will enable more efficient system maintenance, reduced costs, greatly improved reliability, and longer in-service life sustainment.

For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 02-326.

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significantly improved the area of inspection coverage. The thermography inspection was demonstrated by MLSA to detect voids, disbonds, or delaminations as small as 0.25 inches in diameter. The inspection of one doubler can be completed in about an hour using currently available equipment at the depot. The new technology will also eliminate the need for rework (i.e., replacing doublers), since the new NDI has verified that the bonds on the test aircraft had almost no detectable disbonds (>0.25 inches diameter) and displayed no disbonds near the critical zone of the patch's edge.

Successful development and transition of the bonding process and NDI procedure ensures F-15E vertical stabilizer stiffening doublers continue to be a reliable and cost-effective structural reinforcement solution. F-15E flight crews enjoy a greater measure of safety as a result of this innovative engineering effort, and the operational lives of the aircrafts' vertical stabilizers have been extended at a significant savings to the Air Force.

For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 04-203.

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